Nigerian Research Journal of Chemical Sciences **(ISSN: 2682-6054)**
Volume 11, Issue 1, 2023

DESIGN AND CONSTRUCTION OF COMPACT VOLTAIC/GALVANIC CELLS FOR POTENTIOMETRIC ANALYSIS

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ABSTRACT

Voltaic cells are devices capable of generating electrical energy from chemical reactions. Conventional voltaic/galvanic cells are usually simulated using open-fragile glass wares containing electrolytes, which are prone to interference and contamination, loosely fixed electrical wires, electrodes and voltmeters. Simple, compact, sealed and portable voltaic cells were locally designed and constructed using perspex, a transparent and non-fragile material. This was done by allotting dimensions for length: 29.9 cm, breadth: 8.7 cm and height: 8.7 cm, to the cell. Openings for fixing electrodes and paper salt bridge were allotted 0.3 cm × 1.0 cm. Bores for dispensing electrolytes, draining out spent or used electrolytes and for fixing rubber pipe (tubular) salt bridge were allotted 1.2 cm diameter. The cell was partitioned into three compartments: 9.2 cm length x 8.7 cm breadth x 8.7 cm height, 11.5 cm length x 8.7 cm breadth x 8.7 cm height, 9.2 cm length x 8.7 cm breadth x 8.7 cm height, with the compartments, 9.2 cm length x 8.7 cm breadth x 8.7 cm height as two half cells compartments and a central void compartment, 11.5 cm length x 8.7 cm breadth x 8.7 cm height separating the two half cells. Voltmeter was designed to be fixed top of the cell at the 8.7 cm x 11.5 cm space. Electrical wires and crocodile clips were appropriately connected. The cell was validated and compared with conventional one: potential difference produced by various concentrations of electrolytes generated in the constructed voltaic cell was 0.11 ± 0.17, 0.10 ± 0.17, 0.09 ± 0.17, 0.08 ± 0.17 and 0.07 ± 0.17. Volts were higher than potential difference generated in conventional cell: 0.09 ± 0.02, 0.08 ± 0.02, 0.07 ± 0.02, 0.06 ± 0.02 and 0.05 ± 0.02 volts. Lidded half cells and stably fixed Zn and Cu electrodes of the constructed cell against opened half cells and dangling electrodes in conventional cell could be responsible for this. The designed and constructed voltaic cell generated higher electrical energy than conventional cell.

Keywords: Voltaic/Galvanic cell, voltmeter, electrodes, electrical energy, chemical reaction

INTRODUCTION

The paradigm shift in the trend of chemistry from classical method of analysis to instrumental method has to do with system development in the field of electrochemical analysis. Such system development will be incomplete without innovations in the area of voltaic/galvanic cells. Voltaic cells are devices capable of generating or, used to generate electrical energy from chemical reactions [1-5].

Voltaic processes and electrolysis are the basis or fundamental principles of three basic electro-analytical methods: electrogravimetry, potentiometry, amperometry, coloumetry or coulometric titration [6]. Therefore, understanding of voltaic or galvanic cell and electrolytic cell is necessary to have knowledge of such electro-analytical techniques.

Voltaic cells are usually simulated using beakers as vessels for electrolytes with electrodes loosely positioned and flexible electrical wires connected to voltmeter. This assemblage is usually complex as seen in Figure 1.

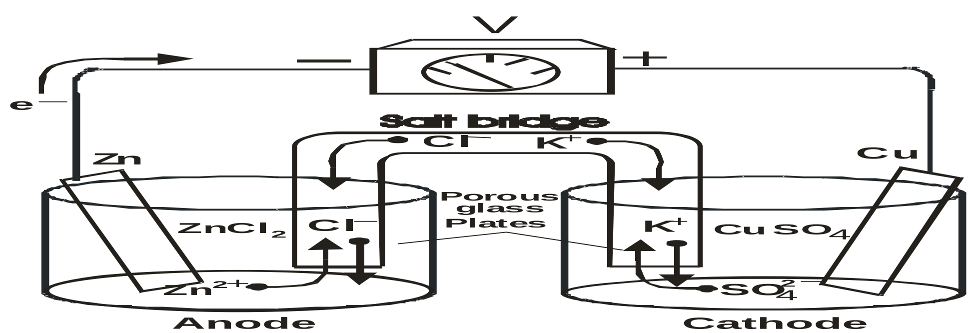


Figure 1: A Typical Voltaic (Galvanic) Cell [7]

Line or cell notation which according to Bard and Faulkner [8] is a shorthand notation employing just two symbols is commonly used to describe electrochemical cells:

/ phase boundary // salt bridge

The cell diagram in Figure 1 is therefore represented by the line diagram:

$Zn_{(s)}$ / $ZnCl_{2\,(aq)}$ // $CuSO_{4\,(aq)}$ / $Cu_{(s)}$

This study designed and constructed simple, non – fragile (durable), compact and portable units of voltaic cells using local materials such that a unit of it can be single - handedly lifted up.

The aim of this study is to create a product that would provide reliable, compact, portable and easy to handle voltaic cells for use in our educational, research and industrial institutions. Specific objectives of this innovation include designing simple, durable – compact, portable units of voltaic cell and validating it using the conventional cell as control.

Working principles and uses of voltaic cells have been reported by Skoog *et al* and SparkNotes[9, 10].

Literatures show that voltaic cells are assembled using beakers, tubes, tanks and troughs as vessels for electrolytes. The following images show various conventional voltaic cells so assembled [11-14].

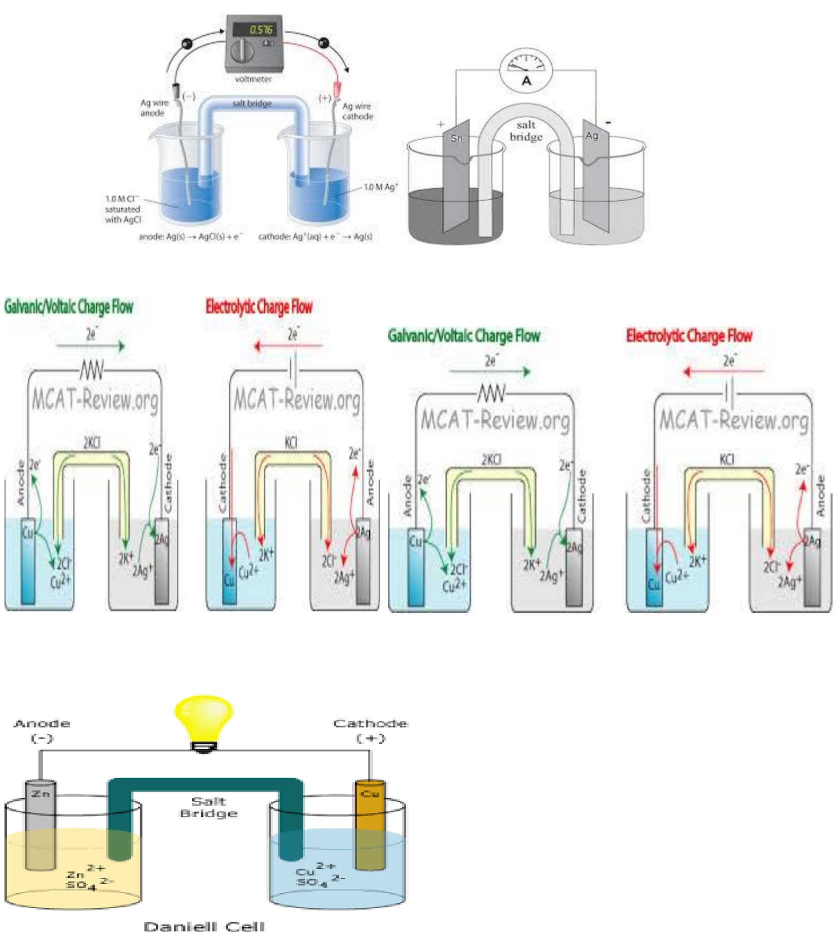


Figure 2: Images of Conventional Voltaic Cells

They are various complexed – simulated forms of conventional voltaic cells consisting of breakable, openned vessels for electrolytes hence prone to inteference and contamination, tubular salt bridges only, dangling electrodes and galvanometers.

Plate 1 shows experimental set ups with conventional voltaic cell.

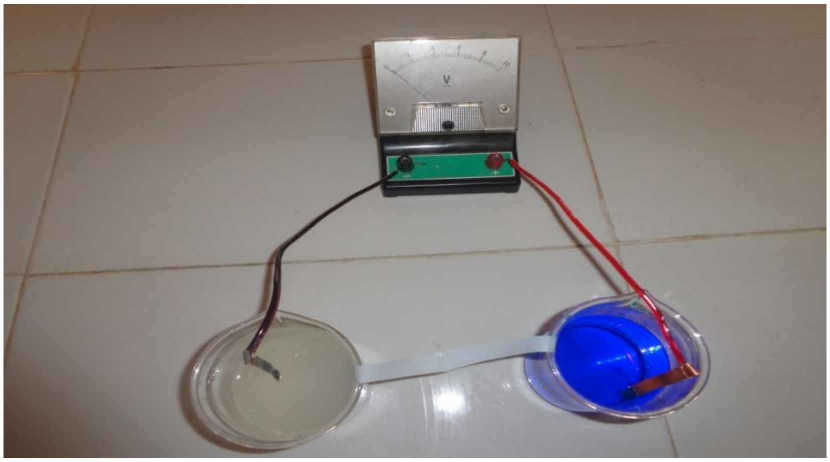


Plate 1: Experimental Set up of conventional voltaic cell

MATERIALS AND METHODS

Apparatus/ Materials and Instruments

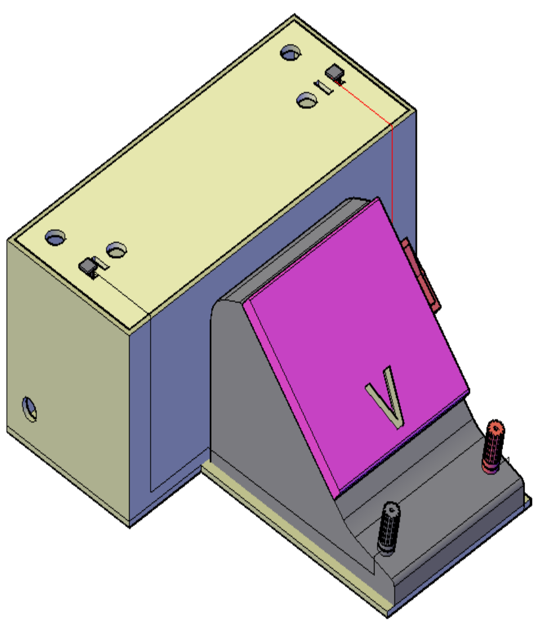
The following apparatus and materials were used: A panels of perspex: 200 x 500mm transparent plastic sheet/plexiglass plate 1mm, meter rule, hacksaw, smoothing file, G-clamp, 4-minute adhesives and silicone, rubber corks, crocodile clips and sandpaper. Others are metal electrodes: copper and zinc, chromatography paper and rubber pipe or hose. The following instruments were used; voltmeters (SEARCHTECH) and a drilling machine: Bosch Professional Impact Drill GSB 570.

Design and construction of voltaic cells

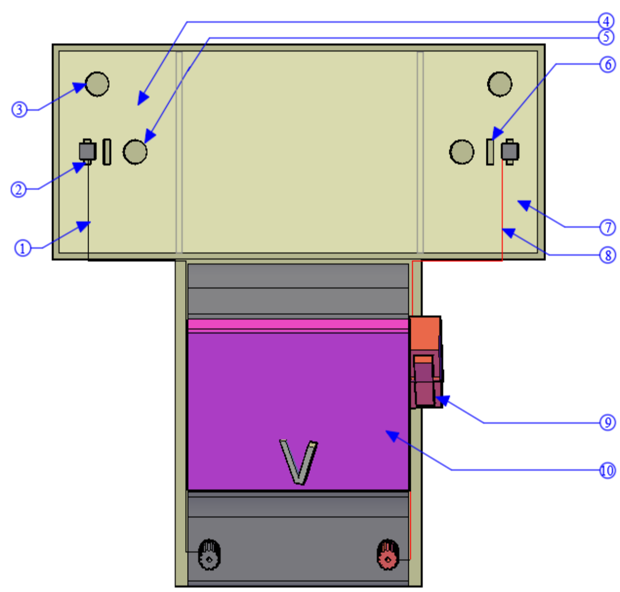
The procedures used by Kelebaone; Ajani *et al*; Frimpong and Forson [15 - 17] were adopted. This was done by allotting dimensions for length: 19.0 cm, breadth: 8.0 cm and height: 8.0 cm to the cell. Openings for fixing electrodes and paper salt bridge were allotted 0.3 cm × 1.0 cm. Bores for dispensing electrolytes, draining out spent or used electrolytes and for fixing rubber pipe (tubular) salt bridge were allotted 1.2 cm diameter. The cell was partitioned into three compartments: 4.0 cm length x 8.0 cm breadth x 8.0 cm height / 11. cm length x 8.0 cm breadth x 8.0 cm height / 4.0 cm length x 8.0 cm breadth x 8.0 cm height with the compartments, 4.0 cm length x 8.0 cm breath x 8.0 cm height as two half cells compartments and a central void compartment, 11. cm length x 8.0 cm breadth x 8.0 cm height separating the two half cells. Voltmeter and an innovated switch were designed to be fixed by the side in front of the central void compartment of the cell. Electrical wires and crocodile clips were appropriately connected. Volume of each half cell of the constructed voltaic cell is 200 cm^3.

A meter rule was used to measure and mark perspex panel into the allotted dimensions specified in the design. The panel was then clamped and cut into required sizes using saw. The top cover and two side pieces were respectively placed on a wooden platform, openings for rubber pipe salt bridge, dispensing and draining off electrolytes, fixing electrodes and paper salt bridge were drilled on them using 1.2 cm drilling bits and chisel.

Surfaces of the sawn pieces perspex were degreased, cleaned and dried. The base was placed on a work bench, partitioned into the three compartments and marked out. Silicone adhesive was then applied to the two central marked partitions on the two sawn pieces of perspex material for the center lines. This was followed by attaching other sawn pieces at the edges and sides of the base, then, the top cover. Voltmeter was fixed to the center of the top cover and appropriate electrodes were fixed as well as a rubber horse (salt bridge vessel). Schemes 1 to 5 show the designed and constructed voltaic cells.



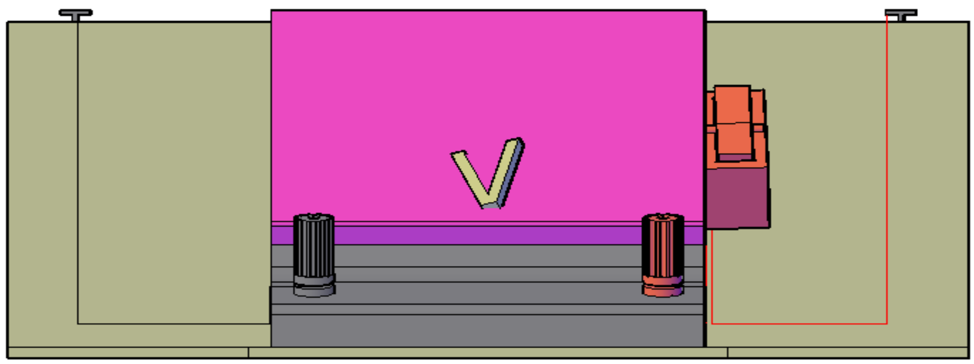
Scheme 1: SW Isometric View of Voltaic Cell



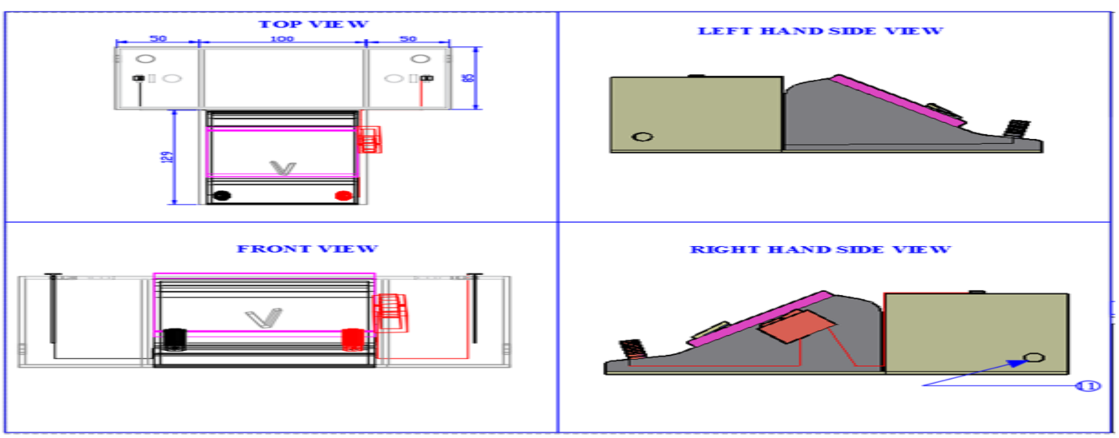
Scheme 2: Top View of Voltaic Cell

Note:

1. Neutral wire 2. Electrolytic opening 3. Dispensing electrode opening 4. A half cell 5.Tubular salt bridge opening 6. Paper salt bridge opening 7. Compartment for second half cell 8. Live wire 9. Switch 10. Voltmeter.



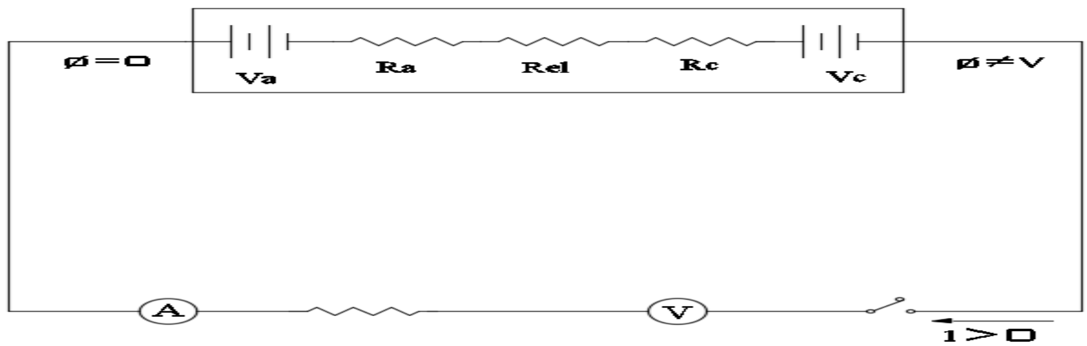
Scheme 3: Front View of Voltaic Cell



Scheme 4: Third angle orthographic view of the voltaic cell

Note:

1. Opening for draining off used electrolyte



Scheme 5: Electrical Circuit Diagram of Voltaic Cell

Plate 2 shows an experimental set up with the cell.

Plate 2: Experimental set up with the constructed voltaic cell

RESULTS AND DISCUSSION

Figure 1 is a typical conventional voltaic cell showing two fragile half-cells made of glass beakers, detachable or removable voltmeter, loose electrical wires, electrodes and salt bridge. Schemes 1 to 5 show different views of design and construction of compact and durable units of voltaic cell indicating two smaller volume of rigid and non-fragile covered or lidded plastic (perspex materials) half- cells, organized electrical wires, fixed voltmeter, fixable electrodes and salt bridge.

Figure 1

↓

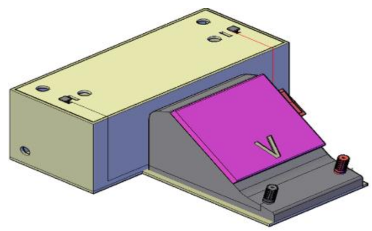


Figure 3: Designed and Constructed Voltaic Cell

Fig. 3 shows a portable – compact designed and constructed voltaic cell made and consisting of durable Perspex material, fixed galvanometer, provision for fixing electrodes, fixing both paper and tubular salt bridges, openings for dispensing and draining off electrolytes as practically seen in plate 2 with an innovated switch and it is interference/ contamination proof because it is lidded.

Differences between Conventional, First and Second Attempted Constructed Voltaic Cell

There are several differences between conventional, first attempted designed - constructed and second attempted designed - constructed voltaic cells some of which are as follows:

i. The conventional voltaic cell is so complex while the designed and constructed voltaic cell is compact and portable.

ii. The two half cells of the conventional voltaic cell are made of fragile glass beakers that are opened and prone to interference and contamination but, half cells of the designed and constructed voltaic cell are made of durable Perspex (plastic) material and are lidded.

iii. Conventional voltaic cell has no switch though it uses salt bridge to connect the two half cells thereby completing its circuit whereas both the first and second attempted designed - constructed Voltaic cells have salt bridge and innovated switch for smooth and better operations and results.

iv. Conventional voltaic cell is larger than the designed and constructed voltaic cells.

The constructed cell was validated by adopting the procedure reported by Shakhashiri [18] to determine electrical energy generated by 1.0, 1.5, 2.0, 2.5 and 3.0 M $ZnSO4.5H2O$ and

$CuSO_4.5H_2O$ respectively compared to electrical energy generated by the same electrolytes using conventional voltaic cell. Results are shown in Table 1.

Table 1: Concentrations of $ZnSO_4.7H_2O$, $CuSO_4.5H_2O$, Potential Difference Generatedusing Conventional and Constructed Voltaic Cell

Concentration of electrolytes (M)	Potential difference (volts)	
	Conventional	Constructed
3.0	0.09± 0.02	0.11 ± 0.17
2.5	0.08± 0.02	0.10 ±0.17
2.0	0.07± 0.02	0.09 ± 0.17
1.5	0.06± 0.02	0.08 ± 0.17
1.0	0.05± 0.02	0.07 ±0.17

Conventional voltaic cells are usually assembled or simulated using fragile beakers, tanks or troughs as vessels for electrolytes with electrodes loosely positioned in the vessels and flexible wires loosely connected to voltmeter [7]. In contrast to these, the constructed compact and durable units of voltaic cell was made ofa non-fragile plastic (perspex material) with organized electrical wires, fixed voltmeter, fixable electrodes, salt bridge and innovated switch. The results show generated electrical energy (potential difference) directly proportional to concentrations of electrolytes with the constructed voltaic cell generating higher energy than the conventional cell.

CONCLUSION

Simple, compact, durable and portable units of voltaic cells were designed and constructed using perspex, a glass like plastic material. Potential difference by various concentrations of electrolytes generated in the constructed voltaic cell: 0.11 ± 0.17, 0.10 ±0.17, 0.09 ± 0.17, 0.08 ± 0.17 and 0.07 ±0.17 volts whereas conventional cell generated 0.09± 0.02, 0.08± 0.02, 0.07± 0.02, 0.06± 0.02 and 0.05± 0.02 volts. Lidded half cells and stably fixed Zn and Cu electrodes of the constructed cell against opened half cells and dangling electrodes in conventional cell could be responsible for these differences.These innovative designed and constructed compact, durable and portable units of voltaic cells are recommended to academicians and educationists for use in laboratories of universities, research institutes, polytechnics, colleges of education and Secondary Schools for better understanding of electroanalytical methods (electrogravimetry, potentiostaticcoulometry and amperostaticcoulometry or coulometry titration) because Stoog *et al* [9] reported that voltaic processes are fundamental principles of these three basic electroanalytical methods.

However other areas to be looked unto include improvement of the cells performance through digitalization, reducing their sizes and interfacing them with computer systems.

The Ministry of Science and Technology is hereby called upon to facilitate mass production of these innovations for use in our laboratories at all levels of education and for exportation as foreign exchange commodities to serve as tools in diversifying Nigerian means of revenue generation even as the current government clamours for.

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